DOCUMENT RESUME

ED 327 708 CE 056 770

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TITLE Measurement Conversions: English and Metric Systems. Fundamentals of Occupational Mathematics. Module 9.
INSTITUTION Central Community Coll., Grand Island, NE.
SPONS AGENCY Office of Vocational and Adult Education (ED), Washington, DC.
PUB DATE 90
CONTRACT V199A90067
NOTE 22p.; For related modules, see CE 056 762-773.
PUB TYPE Guides - Classroom Use - Materials (For Learner) (051)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Arithmetic; Community Colleges; Decimal Fractions; Individualized Instruction; Learning Modules; *Mathematical Applications; *Mathematics Instruction; *Measurement; *Metric System; Number Concepts; Pacing; Two Year Colleges; Vocational Education
IDENTIFIERS *Job Related Mathematics

ABSTRACT

This module is the ninth in a series of 12 learning modules designed to teach occupational mathematics. Blocks of informative material and rules are followed by examples and practice problems. The solutions to the practice problems are found at the end of the module. Specific topics covered include measurement conversions, the English system of weights and measures, and the metric system. (YLB)

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Fundamentals of OCCUPATIONAL MATHEMATICS

Module 9

Measurement Conversions: English and Metric Systems

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Material produced by Central Community College—Platte Campus. Funded by a grant from the U.S. Department of Education, Office of Vocational/Adult Education

CE056 770

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MODULE 9--MEASUREMENT
CONVERSIONS: ENGLISH AND METRIC SYSTEMS

The early history of measurement contains a wide range of units of measurement. Some early length units were based upon a human thumb, hand, foot, forearm or other anatomical features of the ruler (no pun intended) who was in power at that time. Of course, these are not the same from person to person. They, at best, gave them an estimation of measurement. Accurate measurement is the comparison of an observed quantity against a standard quantity. This standard quantity must be one which is constant, accurate and accepted by all who perform technical measurements. The scientific and technical communities now have exact measurement standards which are understood and used by all worldwide.

When converting from one measurement scale to another, most people know that multiplication or division by some number is required. Many people seem to guess at which of the two operations to use. This guessing gives them a 50-50 chance of being correct. To considerably improve this accuracy rate, a person must first learn a systematic scheme to apply when converting from one measurement scale to another. The method which will be demonstrated and applied has a built-in check to determine if the proper operation is being used and will show what the final unit of measure is after a series of steps.

Applications of this conversion scheme will first involve the English system of weights and measures. The metric system will be studied later.

The number 1 (one) has several special properties. If a given quantity is multiplied by 1 (one), the quantity will not change. Secondly, when a number is divided by 1, the quotient is the same as the original number. A third property of the number 1 is that a fraction whose numerator and denominator are the same is equal to 1 (one). These properties mean that a given measurement can be multiplied by a fraction equal to 1 and the result will be equal to the given measurement. Measurement conversion is based upon having a source of fractions which are equal to 1 so that multiplying with these fractions will result in an equivalent quantity with a new unit of measurement.

The Table of English weights and measures below contains quantities which have been defined as equivalent.

TABLE 2	English Weights and Measures
LENGTH	1 foot (ft or ′) = 12 inches (in. or ″) 1 yard (yd) = 3 ft 1 mile (mi) = 5280 ft
WEIGHT	1 pound (lb) = 16 ounces (oz) 1 ton (ton) = 2000 lb
LIQUID CAPACITY	1 pint (pt) = 16 fluid ounces (fl oz) 1 quart (qt) = 2 pt 1 gallon (gal) = 4 qt
AREA	1 mi^2 = 640 acres (A)
TIME	1 minute (min) = 60 seconds (sec) 1 hour (hr) = 60 min

A pair of equal measurements from Table 2 will provide two different fractions equal to 1 (one). The equivalence of 12 inches to 1 foot can be written as a fraction equal to 1 as either $\frac{12 \text{ inches}}{1 \text{ foot}}$ or $\frac{1 \text{ foot}}{12 \text{ inches}}$. These fractions, formed from from equal measurements, are called CONVERSION FRACTIONS.

EXAMPLE 1: Write the conversion fractions which can be formed from 2000 pounds = 1 ton.

Solution: Conversion fractions are $\frac{2000 \text{ lb}}{1 \text{ ton}}$ and $\frac{1 \text{ ton}}{2000 \text{ lb}}$

PRACTICE PROBLEMS: Write each of the following equivalent measures into their two conversion fractions.

1. 1 yd = 3 ft
2. 1 lb = 16 oz
3. 1 gal = 4 qt
4. 1 min = 60 sec
5. 1 mile = 5280 ft
6. 1 pt = 16 fl oz

The recommended procedure for conversion of a measurement of one unit into an equivalent measurement in a new unit will be illustrated by applying the following six steps to change 2.84 feet into inches.

MEASUREMENT CONVERSION STEPS

(1)	Write the original measurement as a fraction with denominator equal to 1.	2.84 ft = $\frac{2.84 \text{ ft}}{1}$
(2)	Select a conversion fraction where the denominator's unit of measure is the unit of measure in the numerator of the original measurement.	ft is original unit $\frac{12 \text{ in.}}{1 \text{ ft}}$
(3)	Write the multiplication of the original measurement and the conversion fraction. Cancel equal units of measure which are positioned in the numerator of one measure and the denominator of the other. The unit of measurement remaining after the cancellation will be the unit of measure in your answer.	$\frac{2.84 \text{ ft}}{1} \times \frac{12 \text{ in.}}{1 \text{ ft}}$ $\frac{2.84 \cancel{\text{ft}}}{1} \times \frac{12 \text{ in.}}{1 \cancel{\text{ft}}}$ $\frac{2.84}{1} \times \frac{12 \text{ in.}}{1}$
(4)	Multiply the numerator numbers and divide by the denominator numbers to obtain the number which is attached to the unit of measure obtained in step 3.	(2.84)(12)÷1÷1 in. 34.08 in.
(5)	The above steps may have to be modified and used repeatedly to achieve the desired final unit of measure.	inch is the desired unit
(6)	The numerical result of a conversion of units should be rounded to the same number of significant digits as there are in the original measurement. The answer needs 3 significant digits.	2.84 has 3 significant digits 34.1 inch

EXAMPLE 2: Change $4\frac{1}{2}$ gallons into quarts.

Solution:

$4\frac{1}{2}$ gallons = $\frac{4.5 \text{ gals.}}{1}$

Conversion fraction needs gallons is the denominator.

$$\frac{4.5 \text{ gal}}{1} \times \frac{4 \text{ qt}}{1 \text{ gal}} = \frac{4.5 \cancel{\text{gal}}}{1} \times \frac{4 \text{ qt}}{1 \cancel{\text{gal}}}$$

$$= \frac{4.5}{1} \times \frac{4 \text{ qt}}{1}$$

$$= (4.5)(4) \div 1 \div 1 \text{ qt}$$

$$= 18 \text{ qt}$$

Only one conversion fraction was required in Example 2 to achieve the required quart unit of measure. Some applications will require a series of conversion fractions to finally have the required unit of measure. Examples 3, 4 and 5 will illustrate how several conversion fractions may be needed.

EXAMPLE 3: Change 25.4 in. into yd.

Solution:

$$25.4 \text{ in.} = \frac{25.4 \text{ in.}}{1}$$

$$= \frac{25.4 \text{ in.}}{1} \times \frac{1 \text{ ft}}{12 \text{ in.}} \qquad \text{unit is ft}$$

$$= \frac{25.4}{1} \times \frac{1 \text{ ft}}{12} \times \frac{1 \text{ yd}}{3 \text{ ft}} \qquad \text{unit is yd}$$

$$= (25.4)(1)(1) \div 1 \div 12 \div 3 \text{ yd}$$

$$= 0.705555555 \text{ yd}$$

$$\approx 0.706 \text{ yd} \qquad \text{3 signf. digits}$$

EXAMPLE 4: Change 125 fluid ounces to gallons.

Solution:

$$125 \text{ fl oz} = \frac{125 \text{ fl oz}}{1}$$

$$= \frac{125 \text{ fl oz}}{1} \times \frac{1 \text{ pt}}{16 \text{ fl oz}} \qquad \text{unit is pt}$$

$$= \frac{125}{1} \times \frac{1 \text{ pt}}{16} \times \frac{1 \text{ qt}}{2 \text{ pt}} \qquad \text{unit is qt}$$

$$= \frac{125}{1} \times \frac{1}{16} \times \frac{1 \text{ qt}}{2} \times \frac{1 \text{ gal}}{4 \text{ qt}} \qquad \text{unit is gal}$$

$$= (125)(1)(1)(1) \div 1 \div 16 \div 2 \div 4 \text{ gal}$$

$$= 0.9765625 \text{ gal}$$

$$\approx 0.977 \text{ gal} \qquad \text{3 signf. digits}$$

When a unit of measure that one wants to remove is in the denominator, then it is necessary to supply a conversion fraction with this original unit in the numerator to accomplish the cancellation. This modification of step 2 occurs when changing units of measure which are associated with a rate of measure type of quantity.

EXAMPLE 5: Change 55 mph into feet per second.

Solution:

$$55 \text{ mph} = 55 \text{ mi/hr} = \frac{55 \text{ mi}}{1 \text{ hr}}$$

$$= \frac{55 \text{ mi}}{1 \text{ hr}} \times \frac{5280 \text{ ft}}{1 \text{ mi}} \qquad \text{unit is ft/hr}$$

$$= \frac{55}{1 \text{ hr}} \times \frac{5280 \text{ ft}}{1} \times \frac{1 \text{ hr}}{60 \text{ min}} \qquad \text{unit is ft/min}$$

$$= \frac{55}{1} \times \frac{5280 \text{ ft}}{1} \times \frac{1}{60 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ sec}} \qquad \text{unit is ft/sec}$$

$$= (55)(5280) \div 60 \div 60 \text{ ft/sec}$$

$$= 80.66666667 \text{ ft/sec}$$

$$\approx 81 \text{ ft/sec} \qquad \text{2 signf. digits}$$

PRACTICE PROBLEMS: Make the following conversions of the unit of measure.

7. Change 3.25 feet into inches.
8. Change 24 ounces into pounds.
9. Change 210 seconds into minutes.
10. Change 2400 pounds into tons.
11. Change 7.13 yd into inches.
12. Change 30.3 inches into feet.
13. Change $2\frac{1}{2}$ gallons into pints.
14. Change 2.40 miles into yards.
15. Change 2,815 inches into miles.
16. Change $1\frac{1}{4}$ hr. into seconds.
17. Change 160 fluid ounces into gallons.
18. Change 30 miles per hour into feet per second.
19. Change 100 feet per second into miles per hour.
20. Change 9.4 pounds per gallon into ounces per pint.

Every area measure is the result of a multiplication of a distance unit by a distance unit. As an illustration, the area obtained by the length times width multiplication of(7 in.)(9 in.) = (7)(9)(in. x in.) is called 63 square inches and is usually abbreviated so that (7)(9)(in.x in.)=63 in.x in.=63 square inches=63 sq in.=63 in^2

Other common English area units are ft^2, yd^2, mi^2 and acre. For the purpose of identifying what unit of measure needs to be cancelled by our system of conversion fractions, in^2 means in.x in., ft^2 means ft x ft and yd^2 means yd x yd. To change from one area unit to another area unit requires the use of two of the same conversion fractions.

EXAMPLE 6: Change 7.00 ft^2 into square inches.

Solution:

$$7.00\ ft^2 = 7\ ft \times ft$$

$$= \frac{7\ ft \times ft}{1}$$

$$= \frac{7\ ft \times ft}{1} \times \frac{12\ in.}{1\ ft} \times \frac{12\ in.}{1\ ft}$$

$$= (7)(12)(12) \div 1\ in.x\ in.$$

$$= 1008\ in^2$$

$$\approx 1010\ in^2 \qquad \text{3 signf. digits}$$

EXAMPLE 7: Change 22.5 yd^2 into square inches.

Solution:

$$22.5\ yd^2 = \frac{22.5\ yd \times yd}{1}$$

$$= \frac{22.5\ yd \times yd}{1} \times \frac{3\ ft}{1\ yd} \times \frac{3\ ft}{1\ yd} \qquad \text{unit is ft x ft}$$

$$= \frac{22.5}{1} \times \frac{3\ ft}{1} \times \frac{3\ ft}{1} \times \frac{12\ in.}{1\ ft} \times \frac{12\ in.}{1\ ft}$$

$$= (22.5)(3)(3)(12)(12) \div 1\ in.x\ in.$$

$$= 29{,}160\ in^2$$

$$\approx 29{,}200\ in^2 \qquad \text{3 signf. digits}$$

EXAMPLE 8: Change 1.0 acre into square feet.

Solution:

$$1.0 \text{ acre} = \frac{1 \text{ A}}{1}$$

$$= \frac{1 \text{ A}}{1} \times \frac{1 \text{ mi}^2}{640 \text{ A}} \qquad \text{unit is mi x mi}$$

$$= \frac{1}{1} \times \frac{1 \text{ mi} \times \text{mi}}{640} \times \frac{5280 \text{ ft}}{1 \text{ mi}} \times \frac{5280 \text{ ft}}{1 \text{ mi}}$$

$$= (1)(1)(5280)(5280) \div 640 \text{ ft x ft}$$

$$= 43{,}560 \text{ ft}^2$$

$$= 44{,}000 \text{ ft}^2 \qquad \text{2 signf. digits}$$

A volume measure is the result of the multiplication of three distance units. Some common English cubic volume units are in^3, ft^3, and yd^3. To change from one volume unit to another volume unit will require three of the same conversion fractions.

EXAMPLE 9: Change 215 ft^3 into yd^3.

Solution:

$$215 \text{ ft}^3 = \frac{215 \text{ ft x ft x ft}}{1}$$

$$= \frac{215 \text{ ft} \times \text{ft} \times \text{ft}}{1} \times \frac{1 \text{ yd}}{3 \text{ ft}} \times \frac{1 \text{ yd}}{3 \text{ ft}} \times \frac{1 \text{ yd}}{3 \text{ ft}}$$

$$= (215) \div 3 \div 3 \div 3 \text{ yd x yd x yd}$$

$$= 7.962962963 \text{ yd}^3$$

$$\approx 7.96 \text{ yd}^3 \qquad \text{3 signf. digits}$$

EXAMPLE 10: Change 980 in^3 into ft^3.

Solution:

$$980\ in^3 = \frac{980\ in. \times in. \times in.}{1}$$

$$= \frac{980\ \cancel{in.} \times \cancel{in.} \times \cancel{in.}}{1} \times \frac{1\ ft}{12\ \cancel{in.}} \times \frac{1\ ft}{12\ \cancel{in.}} \times \frac{1\ ft}{12\ \cancel{in.}}$$

$$= (980) \div 12 \div 12 \div 12\ ft \times ft \times ft$$

$$= 0.567129629\ ft^3$$

$$\approx 0.57\ ft^3 \qquad \text{2 signf. digits}$$

PRACTICE PROBLEMS: Change the given areas and volumes into the indicated unit of measure.

21. Change 28 yd^2 into ft^2

22. Change $100\overline{0}$ in^2 into ft^2

23. Change 192 ft^2 into yd^2

24. Change 1.00 mi^2 into yd^2

25. Change 1 3/4 yd^2 into in^2 (use as 3 significant digits)

26. Change 1/2 acre into ft^2 (use as 3 significant digits)

27. Change 9.0 yd^3 into ft^3

28. Change 72.5 ft^3 into yd^3

29. Change 972 in^3 into ft^3

30. Change 3 1/2 yd^3 into in^3 (use as 4 significant digits)

The International System of Units, abbreviated SI, is the measurement system which is commonly called the metric system. The metric system of units, as it is defined today, is based upon a 300 years old invention of the scientific and technical communities. People of these professions found it nearly impossible to share information of a technical nature using the many measurement systems then in existance. The expanded use of the metric system since its invention is largely due to the expansion of international trade of repairable manufactured products.

It was not until the late 1960's that foreign trade issues had put enough pressure on the United States to force our gradual conversion to the metric system. The change to the metric system in the machine shop will be gradual because of the long life expectancy of the expensive machine tools and measurement instruments. People involved in most phases of manufacture will need to be familiar with both the metric and English systems during the long changeover period.

Below is a list of some common metric (SI) quantities which a person is likely to encounter when working in a machine shop. The metric name of the basic unit of measure and the metric symbol for that basic unit are also listed.

TABLE 3 : BASIC METRIC MEASUREMENT UNITS

Quantity	Metric name	Metric Symbol
length	meter	m
area	square meter	m^2
volume(size)	cubic meter	m^3
volume(capacity)	liter	L
mass	gram	g
time	second	s
force	newton	N
pressure(stress)	pascal	Pa
temperature	degree Celsius	°C
velocity(speed)	meters per second	m/s
angles	degree	°
	minute	'
	second	"
frequency	hertz	Hz
electric potential	volt	V
electric current	ampere	A
elec capacitance	farad	F

The metric system is a decimal system. This means that it is a measurement system which uses powers of 10. There is only one basic unit of measure for each type of quantity, like meter for length. In contrast, the English system contains several units of measure for length; inch, foot, yard, rod, furlong and mile to name just a few. In the metric system a prefix can be attached to a basic unit of measure to form a new unit of measure that is of either smaller or larger size than the basic unit. Each of the available prefixes has a numerical value assigned to it. The numerical value of a prefix is a power of 10. The most commonly used metric prefixes are shown in Table 4 along with their numerical value.

TABLE 4: COMMON METRIC PREFIXES

Prefix	Abbrev.	Decimal Multiplier	Number Value	Written Example	Spoken Name
mega	M	1,000,000	million	MHz	megahertz
kilo	k	1,000	thousand	kg	kilogram
hecto	h	100	hundred	hPa	hectopascal
deka	da	10	ten	dam	dekameter
deci	d	0.1	tenth	dL	deciliter
centi	c	0.01	hundredth	cm	centimeter
milli	m	0.001	thousandth	mg	milligram
micro	μ	0.000,001	millionth	μm	micrometer

Units of measurements are typically written in abbreviated form by using a combination of the abbreviation for the metric prefix and the abbreviation for the basic metric unit of measure.

EXAMPLE 11: Write the name of the metric unit given by the abbreviation

(a) mm
(b) kL
(c) cm^2

Solution:

(a) millimeter
(b) kiloliter
(c) square centimeter

PRACTICE PROBLEMS: Write the name of the metric unit given by the abbreviations

31. cm	32. mg	33. km
34. mL	35. MV	36. kg
37. kL	38. µm	39. dam
40. mm	41. N	42. mA
43. cm^3	44. mm^3	45. m^3

EXAMPLE 12: Write the abbreviation of the metric unit of measure used in the following measurements

(a) 82 centimeters
(b) 1.4 milliliters
(c) 32 kilogram

Solution:
(a) 82 cm
(b) 1.4 mL
(c) 32 kg

PRACTICE PROBLEMS: Write the abbreviation of the metric unit of measure used in the following measurements

46. 19 hectometers	47. 65 milligrams
48. 27 kiloliters	49. 36 microamps
50. 17 millimeters	51. 75 kilograms
52. 8 newtons	53. 28 millimeters
54. 1.5 kilograms	55. 1.5 kilovolt

The remainder of Module 9 will deal only with quantities which are measured using the basic metric unit of meter. These quantities include length along with area and volume which are computed using length. Lesson 10 will cover the other metric quantities.

The basic metric (SI) unit of length or distance is meter, a length just longer than the English yard. For distances considerable longer than the meter, the meter unit is prefixed with multipliers like kilo and mega. For small lengths or distance, the prefixes of centi, milli and micro are used with the basic meter. Table 5 contains equivalent metric lengths.

TABLE 5: EQUIVALENT METRIC LENGTH

1 μm	= 0.000,001 m
1 mm	= 0.001 m
1 cm	= 0.01 m
1 dam	= 0.1 m
1 dm	= 10 m
1 hm	= 100 m
1 km	= 1000 m
1 Mm	= 1,000,000 m

To convert from one metric length to another metric length follow the same 6 steps used in converting English measurements. To convert one prefix of length to another prefixed length usually requires that the original length is first changed to meters before changing to the final prefix.

EXAMPLE 13: Change the following metric lengths to the basic meter length unit.
(a) Change 13.4 mm into m.
(b) Change 0.75 km into m.
(c) Change 82.4 cm into m.

Solution:

(a) $13.4\ \text{mm} = \frac{13.4\ \text{mm}}{1}$

$= \frac{13.4\ \cancel{\text{mm}}}{1} \times \frac{0.001\ \text{m}}{1\ \cancel{\text{mm}}}$

$= (13.4)(0.001) \div 1\ \text{m}$

$= 0.0134\ \text{m}$ 3 signf. digits

(b) $0.75\ \text{km} = \frac{0.75\ \text{km}}{1}$

$= \frac{0.75\ \cancel{\text{km}}}{1} \times \frac{1000\ \text{m}}{1\ \cancel{\text{km}}}$

$= (0.75)(1000)\ \text{m}$

$= 750\ \text{m}$ 2 signf. digits

(c) $82.4\ \text{cm} = \frac{82.4\ \text{cm}}{1}$

$= \frac{82.4\ \cancel{\text{cm}}}{1} \times \frac{0.01\ \text{m}}{1\ \cancel{\text{cm}}}$

$= (82.4)(0.01)\ \text{m}$

$= 0.824\ \text{m}$ 3 signf. digits

EXAMPLE 14: Change the given metric length to the indicated metric length unit.
(a) Change 0.0265 m into mm.
(b) Change 1.435 cm into mm.
(c) Change 142.9 cm into km.

Solution:

(a) $0.0265\ \text{m} = \frac{0.0265\ \text{m}}{1}$

$= \frac{0.0265\ \cancel{\text{m}}}{1} \times \frac{1\ \text{mm}}{0.001\ \cancel{\text{m}}}$

$= 0.0265 \div 0.001\ \text{mm}$

$= 26.5\ \text{mm}$ 3 signf. digits

(b) $1.435\ \text{cm} = \frac{1.435\ \text{cm}}{1}$

$= \frac{1.435\ \text{cm}}{1} \times \frac{0.01\ \text{m}}{1\ \text{cm}}$ unit is m

$= \frac{1.435}{1} \times \frac{0.01\ \text{m}}{1} \times \frac{1\ \text{mm}}{0.001\ \text{m}}$ unit is mm

$= (1.435)(0.01) \div 0.001\ \text{mm}$

$= 14.35\ \text{mm}$ 4 signf. digits

(c) $142.9\ \text{cm} = \frac{142.9\ \text{cm}}{1}$

$= \frac{142.9\ \text{cm}}{1} \times \frac{0.01\ \text{m}}{1\ \text{cm}}$ unit is m

$= \frac{142.9}{1} \times \frac{0.01\ \text{m}}{1} \times \frac{1\ \text{km}}{1000\ \text{m}}$ unit is km

$= (142.9)(0.01) \div 1000\ \text{km}$

$= 0.001429\ \text{km}$ 4 signf. digits

Notice that the process of changing one metric length to another metric length does not affect the sequence of significant digits and rounding is not required to acheive the required number of significant digits. The only change is the location of the decimal point in that digit sequence.

PRACTICE PROBLEMS: Change the following metric lengths to the indicated metric length unit.

56. Change 4.3 m into cm.
57. Change 12.5 mm to m.
58. Change 271 mm into m.
59. Change 763 m to km.
60. Change 7.3 m into mm.
61. Change 0.0134 m into mm.
62. Change 257.3 cm into m.
63. Change 89.7 mm into cm.
64. Change 48.7 cm into mm.
65. Change 1.75 km into mm
66. Change 0.025 km into cm.
67. Change 3.128 mm into cm.
68. Change 26.1 μm into mm.
69. Change 0.058 mm into μm.
70. Change 0.0026 cm into μm.

EXAMPLE 15: Show that 1 cm = 10 mm.

Solution:

$$1 \text{ cm} = \frac{1 \text{ cm}}{1}$$

$$= \frac{1 \text{ cm}}{1} \times \frac{0.01 \text{ m}}{1 \text{ cm}}$$

$$= \frac{1}{1} \times \frac{0.01 \text{ m}}{1} \times \frac{1 \text{ mm}}{0.001 \text{ m}}$$

$$= (1)(0.01) \div 0.001 \text{ mm}$$

$$= 10 \text{ mm}$$

The results of Example 15 will prove to be quite useful. Converting between centimeter and millimeter is a very common problem. Remembering that 1 cm = 10 mm will save a lot of work since one will not need to change to the basic meter unit. This equivalence will be used in (b) of Example 16.

EXAMPLE 16: Change the following metric areas and volumes to the indicated metric area or volume.

(a) Change 937.5 cm^2 into m^2.
(b) Change 6.21 cm^3 into mm^3.
(c) Change 0.391 m^3 into cm^3.

Solution

(a) $937.5 \text{ cm}^2 = \frac{937.5 \text{ cm} \times \text{cm}}{1}$

$$= \frac{937.5 \text{ cm} \times \text{cm}}{1} \times \frac{0.01 \text{ m}}{1 \text{ cm}} \times \frac{0.01 \text{ m}}{1 \text{ m}}$$

$$= (937.5)(0.01)(0.01) \div 1 \div 1 \text{ m} \times \text{m}$$

$$= 0.09375 \text{ m}^2$$

(b) $6.21 \text{ cm}^3 = \frac{6.21 \text{ cm} \times \text{cm} \times \text{cm}}{1}$

$$= \frac{6.21 \text{ cm} \times \text{cm} \times \text{cm}}{1} \times \frac{10\text{mm}}{1 \text{ cm}} \times \frac{10\text{mm}}{1 \text{ cm}} \times \frac{10\text{mm}}{1 \text{ cm}}$$

$$= (6.21)(10)(10)(10) \text{ mm}^3$$

$$= 6210 \text{ mm}^3$$

(c) $0.391 \text{ m}^3 = \frac{0.391 \text{ m}^3}{1}$

$$= \frac{0.391 \text{ m} \times \text{m} \times \text{m}}{1} \times \frac{1 \text{ cm}}{0.01 \text{ m}} \times \frac{1 \text{ cm}}{0.01 \text{ m}} \times \frac{1 \text{ cm}}{0.01 \text{ m}}$$

$$= (0.391) \div 0.01 \div 0.01 \div 0.01 \text{ cm} \times \text{cm} \times \text{cm}$$

$$= 391{,}000 \text{ cm}^3$$

PRACTICE PROBLEMS: Change the given metric measurement to the indicated unit of measure.

71. Change 75 cm^2 into m^2.

72. Change 45 cm^2 into mm^2.

73. Change 983 mm^2 into cm^2.

74. Change 0.082 m^2 into cm^2.

75. Change 915 mm^2 into m^2.

76. Change 1 km^2 into m^2.

77. Change 8.15 cm^3 into mm^3.

79. Change 295 mm^3 into cm^3.

80. Change 84,100 mm^3 into m^3.

The information needed to be able to convert measurements between the English and metric systems would be a list of equivalent values. Table 6 gives all of the equivalence values that are needed for most of the common conversions.

TABLE 6: ENGLISH AND METRIC EQUIVALENTS

Equivalent measures	Three digit conversion	Four digit conversion
1 inch = 25.4 mm	1 inch = 25.4 mm	1 inch = 25.40 mm
1 kg = 2.2046226 lb	1 kg = 2.20 lb	1 kg = 2.205 lb
1 L = 1.05548232 qt	1 L = 1.06 qt	1 L = 1.055 qt

The conversion fraction should be selected so as to have at least the same number of significant digits as the number value of the measurement being changed. For length conversions, the equivalence of 1 inch = 25.4 mm is a definition. This means that it is accurate to every possible number of significant digits. The conversion fractions $\frac{1 \text{ inch}}{25.4 \text{ mm}}$ and $\frac{25.4 \text{ mm}}{1 \text{ inch}}$ are used without any loss of accuracy.

EXAMPLE 17: Change 17.0 in. into mm.

Solution:

$$17.0 \text{ in.} = \frac{17 \text{ in.}}{1}$$

$$= \frac{17 \cancel{\text{in.}}}{1} \times \frac{25.4 \text{ mm}}{1 \cancel{\text{in.}}}$$

$$= (17)(25.4) \text{ mm}$$

$$= 431.8 \text{ mm}$$

$$\approx 432 \text{ mm} \qquad \text{3 signf. digits}$$

EXAMPLE 18: Change 1950 cm into inches.

Solution:

$$1950 \text{ cm} = \frac{1950 \text{ cm}}{1}$$

$$= \frac{1950 \cancel{\text{cm}}}{1} \times \frac{10 \cancel{\text{mm}}}{1 \cancel{\text{cm}}} \times \frac{1 \text{ in.}}{25.4 \cancel{\text{mm}}}$$

$$= (1950)(10) \div 25.4 \text{ in.}$$

$$= 767.7165354 \text{ in.}$$

$$\approx 768 \text{ in.} \qquad \text{3 signf. digits}$$

EXAMPLE 19: Change 2.30 ft^2 into cm^2.

Solution:

$$2.30 \text{ ft}^2 = \frac{2.30 \text{ ft} \times \text{ft}}{1}$$

$$= \frac{2.30 \cancel{\text{ft}} \times \cancel{\text{ft}}}{1} \times \frac{12 \cancel{\text{in.}}}{1 \cancel{\text{ft}}} \times \frac{12 \cancel{\text{in.}}}{1 \cancel{\text{ft}}} \times \frac{25.4 \text{mm}}{1 \cancel{\text{in.}}} \times \frac{25.4 \text{mm}}{1 \cancel{\text{in.}}}$$

$$= \frac{2.30}{1} \times \frac{12}{1} \times \frac{12}{1} \times \frac{25.4 \cancel{\text{mm}}}{1} \times \frac{25.4 \cancel{\text{mm}}}{1} \times \frac{1 \text{ cm}}{10 \cancel{\text{mm}}} \times \frac{1 \text{ cm}}{10 \cancel{\text{mm}}}$$

$$= (2.30)(12)(12)(25.4)(25.4) \div 10 \div 10 \text{ cm} \times \text{cm}$$

$$= 2136.76992 \text{ cm}^2$$

$$= 2140 \text{ cm}^2 \qquad \text{3 signf. digits}$$

PRACTICE PROBLEMS: Change the given measure to the indicated unit of measure. Express the results in the appropriate number of significant digits.

81. Change 8.0 inches into mm.

82. Change 452 inches into cm.

83. Change 4.56 m into inches.

84. Change 8.61 m into feet.

85. Change 7.23 feet into cm.

86. Change 40.66 cm into inches.

87. Change 7.83 inches into mm.

88. Change 27.31 mm into inches.

89. Change 1.000 m into inches.

90. Change 2.40 in^2 into mm^2.

91. Change 96.25 mm^2 into in^2.

92. Change 2.47 m^2 into ft^2.

93. Change 6.51 in^3 into mm^3.

94. Change 7.82 yd^3 into m^3.

95. Change 5184 cm^3 into in^3.

96. Change 281.0 mm^3 into in^3.

PRACTICE PROBLEM SOLUTIONS--Module 9

1. $\frac{1\text{ yd}}{3\text{ ft}}$ or $\frac{3\text{ ft}}{1\text{ yd}}$

2. $\frac{1\text{ lb}}{16\text{ oz}}$ or $\frac{16\text{ oz}}{1\text{ lb}}$

3. $\frac{1\text{ gal}}{4\text{ qt}}$ or $\frac{4\text{ qt}}{1\text{ gal}}$

4. $\frac{1\text{ min}}{60\text{ sec}}$ or $\frac{60\text{ sec}}{1\text{ min}}$

5. $\frac{1\text{ mile}}{5280\text{ ft}}$ or $\frac{5280\text{ ft}}{1\text{ mile}}$

6. $\frac{1\text{ pt}}{16\text{ fl oz}}$ or $\frac{16\text{ fl oz}}{1\text{ pt}}$

7. 39 in.
8. 1.5 lb
9. 3.5 min
10. 1.2 ton
11. 257 in.
12. 2.53 ft
13. 20 pt
14. 4224 yd
15. 0.04443 mi
16. 4500 sec
17. 1.25 gal
18. 44 ft/sec
19. 68.2 mph
20. 18.8 oz/pt
21. 252 ft^2
22. 6.944 ft^2
23. 21.3 yd^2
24. 3,100,000 yd^2
25. 2270 in^2
26. 21,800 ft^2
27. 240 ft^3
28. 2.69 yd^3
29. 0.563 ft^3
30. 163,300 in^3
31. centimeter
32. milligram
33. kilometer
34. milliliter
35. megavolt
36. kilogram
37. kilogram
38. micrometer
39. dekameter
40. millimeter
41. newton
42. milliamp
43. cubic centimeter
44. square millimeter
45. cubic meter
46. 19 hm
47. 65 mg
48. 27 kL
49. 36 μA
50. 17 mm
51. 75 kg
52. 8 N
53. 28 mm
54. 1.5 kg
55. 1.5 kV
56. 430 cm
57. 0.0125 m
58. 0.271 m
59. 0.763 km
60. 7300 mm
61. 13.4 mm
62. 2.573 m
63. 8.97 cm
64. 487 mm
65. 1,750,000 mm
66. 2500 cm
67. 0.3128 cm
68. 0.0261 mm
69. 58 μm
70. 26 μm
71. 0.0075 m^2
72. 4500 mm^2
73. 9.83 cm^2
74. 820 cm^2
75. 0.000915 m^2
76. 1,000,000 m^2
77. 8150 mm^3
78. 0.03521 m^3
79. 0.295 cm^3
80. 0.000,084,1 m^3
81. 200 mm
82. 1150 cm
83. 180 in
84. 28.2 ft
85. 220 cm
86. 16.01 in
87. 199 mm
88. 1.075 in
89. 39.37 in
90. 1550 mm^2
91. 0.1492 in^2
92. 26.6 ft^2
93. 107,000 mm^3
94. 5.98 m^3
95. 316.3 in^3
96. 0.01330 in^3